Summary and Next Steps
Renewable Energy Modeling Series
Forecasting the Growth of Wind and Biomass
April 20, 2004

Results Summary

Introduction
Michael Leifman, U.S. Environmental Protection Agency (EPA) Office of Economic Analysis, introduced the meeting and acknowledged the other sponsors: the EPA's Energy Supply and Industry Branch, the American Council On Renewable Energy (ACORE), the Energy Information Administration (EIA), the U.S. Department of Energy (DOE), and the National Renewable Energy Laboratory (NREL). Michael noted that this fifth meeting in the series would offer updates on wind-energy modeling progress and also examine modeling issues for biomass, a renewable energy resource that had not been specifically addressed in previous sessions. Michael also called for active participation in the day's sessions and invited feedback on future directions for the workshop series.

Session I: Wind Modeling Update

Walter Short, NREL, introduced the wind modeling update session and gave a brief overview of previous discussions in the workshop series of wind modeling. The following notes include comments and discussion from the workshop presentations, and are intended to supplement, but not replace, the presentations themselves.

NEMS Update, Intermittency and Cost
Chris Namovicz, EIA, offered an update on recent improvements to the National Energy Modeling System (NEMS) representation of wind energy. Chris first discussed the capacity credit algorithm. The old algorithm stopped allowing additional use of wind when its penetration reached 20% (Slide 3). The new algorithm uses a probabilistic approach to deal with correlation among different wind sites, which is a function of distance between sites (Slides 4-6). Data to estimate this function was drawn from the Utility Wind Interest Group study of 10 wind sites, which collected detailed temporal wind-generation output data, allowing a pair-wise comparison of these Colorado sites. The average distance between points in region was calculated from the area of each NEMS. Correlation as a function of distance was then calculated, and capacity credit was determined to account for the expected effect of wind on reliability.

Chris also addressed improvements in NEMS regarding representation of surplus wind and overall intermittency issues. Surplus wind occurs because system operators will not turn down base-load plants below a certain level. Curtailment is applied at NEMS region level. Surplus wind is subtracted from overall wind generation, and an adjusted actual capacity factor is calculated (Slides 8-10). Because of the changes to address the capacity credit and surplus wind issues, the 20% cap on wind was changed to raise the cap by 5% per year from 20% to 40%. This ramping in was applied because without it, the model results included very rapid increases in some regions (Slide 11).

Other NEMS projects included review of EIA Form 412 data to try to glean information about capital costs of wind plants throughout the country. Unfortunately, this data has a poor response: despite record numbers of wind projects in 2001, only one wind plant responded that year. Also, the form was designed for fossil, so some questions are inappropriate for wind projects. Chris is trying to work with the Office of Fossil Energy to improve the data (Slide 12).

Chris also highlighted remaining issues, including a need for improved representation of regional wind dispersion. He also cited a need to investigate whether capacity credit should be reduced, because actual peak load periods are much shorter and wind may be less reliably available to meet peak when a shorter time period is considered. (Please see presentation.)

Update on WinDS

Walter Short, NREL, presented recent changes and results from the Wind Deployment Systems Model (WinDS). In describing the WinDS model, he noted that it now includes Class 7 wind (Slide 5). A prominent distinguishing feature of the model is its extensive geographic disaggregation, which includes power control, demand, North American Electric Reliability Council (NERC), and interconnection regions (Slide 6). Direct representation of transmission capacity constraints is another important feature of WinDS. With this information, the model can use actual transmission availability data to estimate how much capacity can be built in one region to serve another region (Slide 7). However, the model only uses annual transmission bottleneck data, and so may miss transmission availability on shorter time frames (Slide 8).

WinDS—because of its geographically and temporally detailed depiction of transmission, intermittency, and available windy land characteristics—can model constraints directly. One example is how transmission cost is estimated as a function of population density, with as much as 2x increases in high-population areas (Slides 8-9).

Walter presented the results for the WinDS base case and other cases. The base case (Slide 10) shows a large increase in wind generation, as well as new coal generation and gas combustion turbines. The model does include cost penalties for rapid growth in wind generation. It also includes a higher rate of learning than in NEMS (Slide 10). Other results presented included an estimate of the cost of a production tax credit (PTC) Extension, which was found to cost the government 0.7 cents per kWh (Slide 13). The wind-generation estimate was also found to be highly sensitive to wind-resource estimate. The new wind resource estimates that DOE's Wind Program has recently performed would reduce the base case 200GW of wind by 2050 to about 120GW, because classes 5 and 6 are now estimated at about one-half the old resource estimate (Slide 14).

WinDS has been used to investigate the possible interactions among wind generation and hydrogen production and storage, fuel cells, and hydrogen transport. The model assesses opportunities for firming the wind power with hydrogen generation at wind sites, for transporting hydrogen from wind sites as fuel to transportation markets, and for using more wind generation from the grid to produce distributed hydrogen at transportation market locations (Slide 15). Based on what cost would be if DOE's hydrogen program met the R&D goal targeted as of June 2003, most hydrogen would be produced as distributed hydrogen, close to transportation markets, which would provide substantial additional opportunities for wind generation (Slide 16).

One of the objectives of WinDS is to provide inputs to other models, such as costs of building transmission to the grid, siting costs, and intermittency costs—each as a function of how much wind was installed. (Please see presentation.)

Comments from the group suggested that costs be expressed without embedding financial assumptions, i.e. in terms of $/kW. The group also discussed the range of $/kW-mile transmission costs that were used in different modeling efforts ($0.50-$1.50). These units for transmission costs were chosen because costs can be varied with length of the line, but not with capacity. In response to a question, Walter clarified that the capacity value given in WinDS is a function of wind penetration and correlation. Land exclusions were also discussed, as well as the differences between old and new wind resource data. Additional data also may become available on time-of-day variability in the wind resource and could be used to look at the question of peak capacity—but this data is not yet available. Another attendee wondered whether the supply curves based on transmission, siting, and intermittency costs would be available for each region, and Walter responded that they planned to aggregate these into larger regions.

NEMS Update, Long-term Costs (Algorithm)
Frances Wood, OnLocation Inc., presented OnLocation's work for EIA to explore possible improvements to NEMS. One goal was to change the algorithm so that the wind supply curve in NEMS would apply its five increasing cost steps independently to each wind class, in each region, so that the different wind classes can compete with each other and different regions can be treated differently (Slide 2). The five costs steps aggregate many factors that are thought to contribute to increasing cost as wind penetration increases. The new algorithm has been applied using old data, and it makes a big difference in places with lots of wind, such as California. New data is being developed by Princeton Energy Resources International (PERI) (Slide 4). This capability is especially important to low wind-speed turbine R&D, because it allows evaluation of the importance of lower-speed resources in direct competition with higher-speed resources (Slide 8).

Further experimental NEMS alterations have been made to explore use of offshore wind. Initially, cost factors were applied so that offshore wind was assumed to be 20% more expensive in shallow water and 50% more expensive in deep water, and offshore wind resources were incorporated into cost curves on that basis. To improve on this, OnLocation represented offshore wind as a different technology within NEMS, so that it would compete separately. Preliminary offshore results were presented. Modeling offshore wind is somewhat different from onshore, because there is less variability in quality of sites, so the primary constraint for offshore wind was the assumption about the maximum growth rate for the technology. Regarding the effect of a PTC on offshore wind, OnLocation modeling found that the effect of a PTC persisted during the time frame up to 2025. This may be compared to Walter Short's presentation of PTC results, which shows that the effect did not persist in the long term. EIA is planning to implement this offshore wind calculation for AEO 2005 (slides 9-10). (Please see presentation.)

Re-evaluating the Wind Long-term Cost Data

Jim McVeigh, PERI, presented work on improvements to the long-term multipliers that are applied to resource costs to represent expected installation cost increases occuring after the best sites have been used. PERI undertook a project for EIA to better estimate these resource multipliers (Slide 3). While the base cost of wind installation is assumed to decline with learning, the long-term multipliers apply a cost increase, so the overall cost depends on both of these functions. Resource degradation is one factor that these multipliers are intended to include. In addition to the resource degradation issues listed in the presentation, Jim also mentioned weather problems at some sites, such as icing or extreme weather conditions (Slide 5).

Jim noted a few details on the transmission and interconnection costs (Slide 12). Regarding the second item, he clarified that wind resource is not usually next to existing lines, but that these sites could be chosen if they were available. Also, with regard to the regional variation in transmission costs, the lower end of this range may actually be below $3.7/kW-mile.

Slide 15 shows the new method for applying long-term multipliers independently to each wind class. Overall, Jim noted that the effect of the long-term multiplier will become significant only after a large amount of wind has been installed.

Regarding Slide 18, Jim explained that new methods to address site-accessibility issues may allow for consideration of resources on steeper slopes, with an additional cost factor. Also on that slide, the average capacity factor considers some of the issues in the "Energy Production" category of costs. Considering this issue further, Jim clarified that it is important to understand whether the average capacity factor for a given wind class is appropriate for the first set of wind sites in each class, before the degradation costs are applied (Slide 20).

Market factor costs associated with local control of permitting processes do have an impact on wind development. The issue for the long-term multiplier estimate is the question of where on the supply curve—and to what extent—these issues will increase wind cost (Slide 21).

Jim outlined some next steps, including addressing whether areas with slope greater than 20% could be included (and at what cost increment), and also developing GIS data that fully accounts for other wind siting issues (slide 24). Please see presentation.

Questions and answers about the wind session addressed incorporation of changes in the version of NEMS that was used for AEO2004. Frances' and Jim's presentations included algorithm and data development work that has not been incorporated into NEMS yet; but AEO 2004 has many of the improvements that Chris presented, as noted in his presentation. Further questions addressed how the WinDS assumptions differ from the new NEMS approach. Generally speaking, WinDS applies more restrictive constraints, but more favorable wind cost assumptions. An attendee also asked whether any effort has been made to estimate the economic benefits of wind developments, which has not been done in theses studies. Further discussion ensued on land-use issues, and it was explained that high land values tend to imply siting difficulties. Land-use exclusions don't include opportunity costs, and it was discussed that different types of geographic data at high resolution would be needed to assess these siting issues—but would be difficult to collect on a general basis.

Session II: Forecasting the Growth of Biomass

Zia Haq, EIA, introduced the biomass session. This was the first workshop session dedicated to biomass, and Zia explained that it was intended to provide a broad overview of biomass resource use and related modeling issues. The presentations addressed characterization of biomass supply as well as the diverse uses of biomass, including ethanol, biopower, and higher-value biomass-based chemicals. As before, the following notes include comments and discussion from the workshop presentations, and are intended to supplement, but not replace, the presentations themselves.

Potentially Useful Analytic Information from Biomass R&D Activities
Tien Nguyen, DOE, described analytic information regarding DOE's Biomass R&D program. Emerging biorefinery technologies are the focus of much research, and some of these may become operational within the next five to six years (Slide 6). Specialty biorefineries that produce a single product or several products in parallel may be developed. Research on biorefineries for bio-based products is funded through the Interior appropriations bill (Slide 8). Higher-value chemical products are being targeted with the hope that these will improve overall profitability, but that will depend on process costs (Slide 11).

Tien provided information regarding energy crop potential. Energy crop research is no longer funded by DOE, but only by the U.S. Department of Agriculture (USDA) (Slide 12). Currently, ethanol is produced solely from corn kernels. DOE envisions that in the near-to-mid-term, ethanol can be produced from the corn fiber, which will result in a 10% capacity addition compared to current production levels. In the mid-to-long-term, ethanol production could be increased by 100% over current levels if corn stover, agricultural residues, some forest residues, other wastes, and some energy crops could be utilized. A participant asked why future ethanol production could not solely rely on corn and current technologies. Tien explained that current production from corn could only be increased by a factor of 2 to 3.5, without an effect on price and quantities of animal feed. Therefore, the research on alternative feedstocks will allow ethanol production to expand without impacting current markets for corn (slide 13).

Regarding land-use changes and greenhouse gas effects, Tien emphasized the importance of evaluating net effects, because of the significant impact of land-use changes on greenhouse gases (Slide 14).

Energy crop potential is estimated using an agricultural supply and demand model called POLYSYS at the University of Tennessee and Oak Ridge National Laboratory (Slide 15). Ethanol demand analysis is conducted using a model at Oak Ridge National Laboratory (ORNL). This includes effects of resource constraints and policy assumptions (Slide 16). Ethanol logistical analysis is performed by Downstream Alternatives, which has national expertise on fuels distribution and logistics (Slide 17). Constraints on ethanol use include: blending limitations, infrastructure costs for E85, insufficient volumes to justify pipelines, challenges to identify most lucrative bio-based products, and potential lack of good markets for coproduced electricity near biorefineries (Slide 18). Tien noted that nearly half of the biomass budget this year went to congressionally directed projects, which has posed significant challenges for R&D and analysis.

Development of a Biorefinery Optimization Model
Mark Ruth, NREL, discussed a biorefinery optimization model that is being developed for long-term, not current or near-term, biorefineries. This analysis is being conducted to support identification of R&D opportunities, and also to assist in benefits analysis (Slide 4). Ethanol process analysis is being conducted to calculate a minimum ethanol selling price (at plant gate) needed to achieve a target rate of return. This price does not include distribution cost, infrastructure cost, or tax credits (Slide 4). The engineering economic analysis uses ASPEN+, but also includes processes such as wastewater treatment, and ethanol recovery, that are not part of ASPEN (Slide 5). Slide 6 depicts a flow chart of a biorefinery, showing what could be developed as a result of R&D efforts. These models help R&D planners determine the program goals that would be needed to make biorefineries economically feasible (Slide 7). Additional analytic work on biomass gasification and hydrogen production from synthesis gas will include a formal design report and assessment of specific potential markets (Slide 10). Because there are so many potential biorefineries that could be designed, NREL is seeking to develop a single model that can combine many different processes and potential pathways (Slide 12). One step toward analyzing many alternatives rapidly is the development of a spreadsheet-based linear program called ‘Biorefine.xls’ (Slide 13).

Discussion focused on the extent to which the simplified biorefinery model allowed assessment of effects from different feedstock chemistries. Mark said that carbohydrate level is the input variable that characterizes the different feedstocks, but specific chemical reactions are not depicted. Scenario capability, especially to depict market changes, is currently under development. The simplified Biorefine.xls model will be completed this summer, and EIA would like to use it to determine potential integration issues with large models such as NEMS.

The Future Role of Biomass Using the ObjECTS (MiniCAM) Framework
Steve Smith, Pacific Northwest National Laboratory, presented the modeling of biomass use within the Object Oriented Energy, Climate, and Technology Systems

(ObjECTS), Mini Climate Assessment Model (MiniCAM) framework. This framework treats the United States as a single region (Slide 5). Biomass is assumed to be available as a residue stream or as an energy crop. The residue stream availability data is derived from the EIA regional supply schedule. There are plans to disaggregate this schedule into the different type of residues (Slide 6). Allocation of agricultural land use occurs through competition of crop land with other agricultural land uses, as well as competition among different crops for the crop land (Slide 8). Because there are many biomass resources and potential end uses, the modeler must address difficult questions as to how to combine or distinguish different elements and which details are most important to include (Slide 9). MiniCAM included only major liquid fuel uses in the transportation sector (Slide 10). ObjECTS represents a refinement over MiniCAM including a refined liquids sector and explicit representation of ethanol production and use. Some illustrative results were presented to show the effect of assumptions about ethanol vehicle and infrastructure costs (slide 12 through 15). The results suggest that the total amount of biomass used in the United States increases substantially if 100% ethanol vehicles are available at a slightly higher cost than gasoline fueled vehicles and if greenhouse gas emissions are constrained.

Current Issues in the Forecasting of Weather-Driven Renewable Energies
Ken Westrick, 3TIER Inc – ACORE, the luncheon speaker, addressed topics beyond the biomass scope of Session II. He expressed ACORE's eagerness to work more closely with the modeling workshop series and its participants, and also highlighted the importance of renewable energy modeling and analysis to ACORE's educational mission. He described work on renewable energy-forecasting issues and noted the value of forecasting services to the industry. In particular, he raised important questions about evaluating the potential for correlation or complementarity of wind generation with other generation, especially hydropower. The interannual variability of some wind resources is correlated with dry years that limit hydropower, whereas other wind resources complement the hydropower because drier years are windier. He pointed out that this type of assessment is very important to wind developers and utility planners.

Modeling Biodiesel and Ethanol in the National Energy Modeling System
Tony Radich, EIA, described EIA estimates of ethanol use in the transportation sector, and compared this to other estimates. EIA tracks transportation use of the oxygenates ethanol and MTBE. EIA estimates the price of corn for ethanol production, and the effect of forecasted corn prices on ethanol price and production, as summarized in a study for Senator Tom Harkin (Slide 6).

Biomass Feedstock Analysis
Bob Perlack, Oak Ridge National Laboratory, discussed a paper that ORNL is preparing that analyzes the DOE's "Feedstock Roadmap" goal and the current status of biomass feedstock supply analysis. The DOE's biomass program has established a biomass feedstock vision that would require obtaining a billion tons per year for use in biopower, transportation fuels, and bio-based products. The ORNL vision paper is further exploring these feedstock goals, including examination of resources from forests and agricultural lands (Slides 2-8). Major agricultural residues are corn stover and wheat

straw, with others comprising a small fraction of residue (Slide 9). The POLYSYS agricultural-sector model, which looks at agricultural production in 350 agricultural districts, has explicitly included agricultural residues (Slide 9), by modeling farmers' decisions with income streams from both crops and residues. This model can assess the relative competitiveness of different crops and is used to generate supply curves for energy crops.

The supply curves for corn-stover collection reflect limits of efficiency of equipment and environmental constraints to prevent erosion and preserve soil biomass. The right-most curve represents more equipment investment, enabling more biomass collection, whereas the left-most curve represents what could be achieved with little additional capital and no additional operational costs (Slide 11). Cost includes removal, storage and transport to field edge, and compensation for nutrient loss, but not cost for further transport. Additional costs may result in a total cost of $35-$50/dry ton to get stover to a hopper at a plant in unbaled form. The discussion highlighted that this work does not include additional cost, potential profit, and risk to the farmer. Agricultural residues are currently harvested by going over the field in multiple passes. A one-pass system that harvests and collects residue simultaneously is necessary to reduce collection costs. The total corn stover supply estimate of 216 million dry tons is the estimate before environmental constraints are applied (Slide 12). Consideration of soil quality constraints reduces the amount available to 65 to 110 million dry tons per year.

Supply schedules for energy crops were estimated in the late 1990s using an old version of POLYSYS. Energy crops would need to supply a substantial portion of the 1 billion ton goal.

Biomass Supply Schedule and Biomass for Electricity Forecasts using NEMS
Zia Haq, EIA, addressed biomass for electricity generation. EIA has assessed the effect of a production tax credit (PTC) on cofiring of biomass with coal. That effect turns out to be very short-lived if the credit is temporary. Greenhouse gas and mercury emissions constraints have a significant impact on biopower's market share (Slide 3). NEMS modeling allows up to 15% biomass use for cofiring biomass with coal (on a heat input basis) (Slide 5). Zia presented the relative capital cost of different technologies, which shows that biomass IGCC technology is relatively costly (Slide 7). Availability of biomass is a crucial issue for biopower, and EIA's data (from ORNL and Antares Corporation) shows a maximum of 8.28 Quads (482 million dry tons per year) of available biomass in the U.S. Biomass transportation cost is an important element, and EIA uses $10 per dry ton as an assumption (Slide 11). A variety of analyses have been performed that help address the question of drivers for biopower. Renewable portfolio standard (RPS) analysis suggests that biopower is not used much at a 10% RPS level, but starts to gain significant market share with a 20% RPS. These results could be affected by changes of NEMS' wind calculations (Slide 17). Questions from the audience suggested that further work needs to be done to disaggregate the DOE goal of 1 billion ton of biomass so that they can be compared to existing biomass resources (Slide 19).

Discussion

It was suggested that land use may not be the primary constraint on attaining the vision of one billion ton of biomass use. Instead, the cost of obtaining a billion tons of feedstock may be higher than markets are willing to pay. Another question related to the energy input-to-output ratio of ethanol, and workshop participants noted that USDA energy-balance studies of corn ethanol production answer this definitively. Discussion about how NEMS might incorporate data on high-value products raised the possibility that cost and supply could be calculated exogenously and those results could be used in NEMS. One participant wondered why cofiring was not permanently increased through the use of a PTC, and this is because the major cost of cofiring is fuel cost, not capital cost. The production tax credit helps encourage projects that are just on the margin of profitability. The issue of NEMS' handling volatility in natural gas price also was raised. It was clarified that NEMS addresses major structural changes, and a different type of model would be better suited to answer this question. Further discussion focused on the value of reducing uncertainty in forecasting, and participants noted that wind uncertainty is a major issue in wind project finance. However, they noted the value of reducing uncertainty depends heavily on how much can be saved with greater certainty.

Speakers offered brief comments on the major insights that they gained from the days' work. Chris Namovicz said that recent work has achieved better treatment and understanding of intermittency issues, and remaining issues include implementation of intermittency calculations and data and algorithm issues, such as those addressed by Frances Wood and Jim McVeigh. Walter Short noted that the comment that capacity value is determined by wind contribution during peak load reiterated the importance of using time-of-day wind resource data. He also pointed out that Jim's work (long-term multipliers) will be very influential, and that it will be important for his work to incorporate as many considerations as fully and accurately as possible. Transmission cost issues may be especially important. Jim highlighted that in the long-term multipliers work, the key issue is to think about the total maximum cost, and to develop a clear understanding of whether a 2x or 3x cost multiplier is justifiable. He said that some results of WinDS will be used to estimate certain cost elements.

Mark Ruth commented on the complexity of biomass products and supply. He suggested that the most important next step for achieving good estimates of bioenergy potential was the completion of the ORNL vision paper, which will provide a better understanding of what resources are really available and at what cost. Conversion issues for current and future technologies were also an important consideration. Bob Perlack highlighted resource issues, and the complexity of the biomass supply chain, as challenges for modelers, whereas biopower itself is relatively simple, because it can be dispatched and used for base load. He cited the importance of clarifying what supplies and technologies are available now and also getting a better sense of how technologies will evolve, especially with respect to crops and their yields, and options to achieve sufficiently low-cost collection technology and perhaps higher energy density during transportation. Mark commented that real and perceived sustainability issues might be added to this list. Steve Smith reiterated the importance of understanding near- and long-term biomass supply, the reasons for the differences between the two, and all assumptions used to estimate both. Ken Westrick highlighted the need for evaluating correlation or complementarity of weather-driven resources, and suggested that such variability issues may eventually need to be addressed in NEMS. Tony Radich noted the importance of questions such as the ultimate design of biorefineries, prices for bioproducts, and market size and price for niche markets for biofuels.

In conclusion, Michael Leifman sought feedback from the group on future workshop directions, including the possibilities of another biomass session or taking on other technologies. Steve Smith pointed out that solar is a major alternative in the longer term, and Chris and Ken noted the question of whether the workshop should focus on lower-cost, nearer-term technology issues, such as hydro and others, or on solar, which has a small share now but may be important in the long term. Eldon Boes, NREL, noted the substantial remaining questions in estimation of biomass resource potential, and suggested that presentations on the ORNL vision paper, once complete, might be of great interest. Offshore wind also was suggested as a potential topic. Ben Bedouani, Natural Resources Canada, offered that he would be happy to share perspectives on renewable energy modeling issues for Canada. Zia Haq noted that modeling for renewables may need to address increasingly international renewable energy markets, with possibilities that Canadian hydropower, Brazilian and Caribbean basin ethanol may become important suppliers to the United States if high petroleum prices are sustained.